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Preliminary study after two years of use of Nausicaa system for seasickness management

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ABSTRACT

Background: *Seasickness is a set of clinical signs from which approximately 30% of the population suffers with a severity and frequency that varies according to the state of the sea and according to each individual susceptibility. The medical treatments are varied but may provide annoying side effects. Vestibular rehabilitation has all its advantages in cases of professional unfitness. The objective of this work is to validate the first results of rehabilitation of seasickness using the Nausicaa system developed at the HIA in Brest.*

Materials and methods: *Retrospective study of the first 2 years of use of the Nausicaa system, from commissioning in November 2016 until December 2018. Twenty-eight patients were treated exclusively by the Nausicaa system with a minimum of 1 year of follow-up and a minimum of 90 days at sea per year.*

Results: *The average intensity of seasickness of these sailors decreased from 8.96 to 4.5 and the inability to hold one's post from 8.36 to 3.7 after 10 rehabilitation sessions using this system. The Graybiel and Miller score was markedly improved (decrease of 2 to 3 grades) in 62% of the patients, and partially improved (decrease of one grade) in 20% of the sailors. A total of 82% of rehabilitated patients were improved by this treatment without any side effects.*

Conclusions: *The analysis of the results on a retrospective questionnaire describing clinical signs 1 year later is necessarily subjective. The use of visual analogic scales from 1 to 10 concerning the intensity of motion sickness and the inability to hold one's position seems to be an easy way to assess discomfort. The comparison with other series seems to show a slight superiority of the Nausicaa system compared to optokinetic rehabilitation or by visual simulator alone.*

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Key words: sea sickness, motion sickness, virtual reality, sensory conflict, vertical stimulation

INTRODUCTION

Seasickness is the motion sickness generated by the maritime environment. It is the most problematic motion sickness in terms of its intensity and frequency in subjects [1]. Given the impact of the symptoms, sailors risk having to avoid going to sea, which can lead them to professional unfitness [2], and boaters risk giving up their leisure activity.

Information from peripheral sensors is integrated at the central level. A neurosensory conflict results from the integration of both a real movement and an false perception of immobility [3–5]. It provokes neurovegetative reactions sometimes extremely debilitating.

A wide range of therapies can be used [5, 6]. Their effectiveness, however, is variable, each subject responding differently in terms of improvement or side effects. Artificial exposure to mechanisms generating clinical signs often allows for habituation [7, 8]. Vestibular rehabilitation exercises based on optokinetic stimulation, when practiced, have given good results [8–10].

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The development of the management of vestibular and balance rehabilitation has for some years relied on virtual reality [11]. In the case of seasickness, the vertical component of the stimulation feels particularly uncomfortable and thus aggravates clinical signs [12, 13]. With this in mind, we have developed a system (Nausicaa) whose objective is to propose a greater range of vestibular stimulation by adding a vertical component, movements that are particularly harmful to the sailor. Thus, a seat performs vertical movements in order to stimulate the saccule while the subject is experiencing a virtual reality simulated navigation.

The results of the first patients who were able to benefit from this new method of preventing seasickness are reported below.

MATERIALS AND METHODS

This is a retrospective study of the first 2 years of use of the Nausicaa system, from its commissioning in November 2016 until November 2018. Self-administered questionnaire was used in addition to the information found in the subjects' medical files. The studied files concerned patients who benefited from seasickness rehabilitation using the Nausicaa platform, sailing at least 90 days a year, between November 2016 and November 2018.

Fifty-six files were identified. Ten files were excluded due to incorrect or invalid email addresses. Eight were excluded due to sailing less than 90 days. Ten did not reply despite 3 reminders. Twenty-eight subjects were then selected.

Patient care consisted of a clinical examination supplemented by cochleo-vestibular explorations (audiometry, tympanometry, videonystagmography, cervical Vestibular Evoked Myogenic Potential, posturography) in order to make ensure the correct running of the inner ears.

Seasickness was assessed with the Graybiel scale and with a Visual Analogue Scale (VAS). Similarly, working-on-board inability was assessed with a VAS. Other parameters likely to induce seasickness were found in the patient files.

Each patient received 10 rehabilitation sessions using the Nausicaa system (Fig. 1).

This system has been designed and developed by our department in conjunction with the French Government Defence procurement and technology agency (Direction Générale de l'Armement), Actris and the European Centre for Virtual Reality. It generates a sensory conflict using virtual reality instead of optokinetic stimulation and combines it with vertical movements in order to stimulate the saccule. The seat is enslaved to virtual reality so that the movements of the chair are correlated to the swell generated by virtual reality (Figs. 2 and 3). It allows a vertical range of 1.4 m.

The rehabilitation protocol includes 10 sessions of increasing difficulty (by changing the height and direction of the swell, the presence of cross seas, the presence of yawing of the boat). During the sessions, the subject may be asked, as in the case of optokinetic rehabilitation, to perform head movements.

Figure 1. Nausicaa system

Figure 2. Nausicaa system in operation

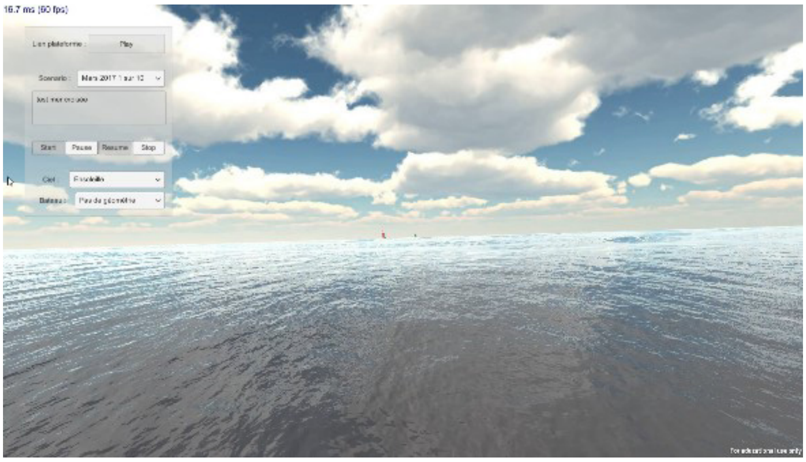

Figure 3. Screen shot of virtual reality (operator view)

Data were analysed with R software version 4.1.2 (2021-11-01). Mean, standard deviation, median and minimum–maximum values were given for descriptive statistics. Results were compared with Wilcoxon test for paired series and Fisher test. $P < 0.05$ was considered statistically significant.

RESULTS

The subjects included 17 (62%) men and 11 (38%) women (Table 1). The average age was 33.18 ± 11.2 years. The average age for men was 32.76 years and 33.81 for women, with no significant difference ($p = 0.795$). The distribution of professions shows 13 military personnel, 10 civilian marine professionals, 4 yachtsmen and a specialised photographer. The average of days at sea was 145 ± 56.6 days (values of 90 to 240 days at sea).

Otoscopic examinations, pure tone audiometers and speech tests were normal.

Several characteristics of the seasickness of these patients were noticed during their initial medical exam (Table 2). Smells (particularly fuel and cooking) were reported to be aggravating for 20 subjects. Similarly, it illustrated that the vertical component of the movement of the boat were more likely to increase clinical manifestations for 20 subjects. The presence of motion sickness in childhood was also found for many subjects (n = 20). Seasickness does not seem to be part of a broader set of motion sickness since in our population only 39% of subjects reported having discomfort in other transportation types in adulthood.

We did not find any psychological characteristics in patients with seasickness: no claustrophobic (82%), agoraphobia (85%), psychiatric history with depressive or anxio-depressive syndromes in our population (89%). Nevertheless, nearly 30% of subjects showed heights dizziness symptoms.

Table 1. Baseline characteristics of the seasickness population

Parameters	N = 28
Age [years]	33.18 (11.20)
Sex	
Male	17 (60.71%)
Female	11 (39.29%)
Professional category	
French Navy	13 (46.43%)
Merchant Navy	4 (14.28%)
Fishermen	3 (10.71%)
Hydrograph	3 (10.71%)
Boater	4 (14.28%)
Photographer	1 (3.57%)
Days at sea	145 (56.60)

Data are number (%) or mean (standard deviation).

Finally, very few patients (14%) reported discomfort on their return to land and none described a mal de débarquement syndrome, as defined by a duration exceeding 1 month. The return to land discomfort is manifested by a feeling of instability during the few hours or days following the return to solid ground.

Sea sickness and inability to hold one's position on board were assessed by VAS before and few months after the rehabilitation protocol (Table 3). In our population we assessed seasickness at 8.68 initially against 4.46, a significant improvement ($p < 0.0001$). Similarly, the inability to work on board decreased from 8.39 to 3.71 after rehabilitation. Here again the difference is significant ($p < 0.0001$). The improvement remains clear and significant according to gender.

Table 2. Characteristics associated with seasickness number (proportion)

Parameters	Yes	No	Do not know
Extrinsic factors			
Smell	20 (71.43%)	5 (17.86%)	3 10.71%)
Vertical component of motion	20 (71.43%)	3 (10.71%)	5 (17.86%)
Intrinsic factors			
Psychiatric history	1 (3.57%)	25 (89.29%)	2 (7.14%)
Heights dizziness	8 (28.57%)	18 (64.29%)	2 (7.14%)
Claustrophobia	2 (7.14%)	23 (82.14%)	3 (10.71%)
Agoraphobia	2 (7.14%)	24 (85.71%)	2 (7.14%)
Maritime experience in childhood	11 (39.29%)	15 (53.57%)	2 (7.14%)
Motion sickness history	20 (71.43%)	6 (21.43%)	2 (7.14%)
Motion sickness in adulthood	11 (39.29%)	15 (53.57%)	2 (7.14%)
Discomfort when returning to land	4 (14.29%)	22 (78.57%)	2 (7.14%)

Table 3. Results of seasickness treatment using Nausicaa system

Parameters	Before	After	P
Sea sickness	8.68 [8–9.50]	4.46 [3.49–5.50]	< 0.0001
Male	8.35 [7.56–9.15]	4.29 [3.16–5.43]	< 0.0001
Female	9.18 [8.45–9.91]	4.72 [3.25–6.21]	0.0002
Working-on-board inability	8.39 [7.99–9.51]	3.71 [2.99–5.00]	< 0.0001
Male	7.94 [6.99–9.01]	3.12 [2.01–5.00]	0.0005
Female	9.09 [9.49–10.00]	4.63 [3.50–6.51]	0.0006

Data are mean [confident interval].

The score obtained on the Graybiel scale before and after treatment, allowed us to order the patients within 4 groups: slight malaise, moderate malaise, severe malaise and frank malaise (Fig. 4). Initially, the patients were all found in groups 3 and 4 (5 at group 3 and 23 at group 4), the most severe.

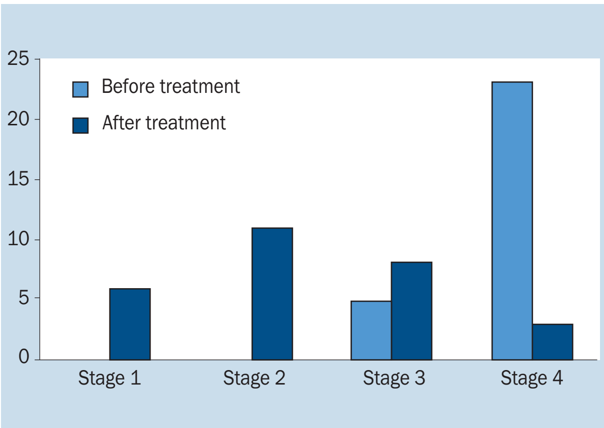

Figure 1. Graybiel's score stages before and after treatment

After rehabilitation, the patients' distribution changed in favour of groups 1 and 2 (6 at group 1, 11 at group 2, 8 at group 3 and 3 subjects remaining at group 4). We would describe it as a partial improvement in case of a reduction of 1 group (n = 6, or 21%) and a frank improvement for the reduction of 2 or 3 groups (n = 17, or 61%). The improvement distribution thus observed towards the first groups was statistically significant (Fisher test p = 0.04).

Among these parameters we observed a correlation coefficient of 0.59 (Pearson correlation test, p = 0.0008) between the intensity of seasickness before and the resulting operative inability (assessment by VAS). This coefficient dropped to 0.38 (p = 0.04) for the link between on-board inability and the Graybiel scale. This correlation between Graybiel score and intensity of the initial naupathy was calculated at 0.29 (p = 0.12).

After rehabilitation, we observed a strong link between intensity of residual seasickness and Graybiel score (r = 0.697, p < 0.0001) and working-on-board inability (r = 0.51, p = 0.005). The correlation between the working-on-board inability after treatment and the Graybiel score was 0.36 (p = 0.58)

DISCUSSION

The low number of studied subjects can be explained thanks to several factors. First of all, it was necessary to set a relatively high number of annual days at sea, in order to have a regularly exposed population and allow a more realistic assessment of seasickness. In effect, this meant ruling out many patients. Furthermore, during the study period, i.e., the beginning of use of Nausicaa, a certain number of patients were undergoing rehabilitation with optokinetic stimulation protocol, thereby reducing the number of potential subjects eligible for this study. Finally, as often, the retrospective nature of a study translates into a certain loss of information. We have clearly observed this in the number of subjects we were unable to submit the questionnaire or subjects not answering the questionnaire.

Our population has an average age of 33.18 years. This young age is partly explained by the profession of the subjects and in particular the military status of nearly half of them.

This age is similar to that observed by Trendel et al. in 2010 [8], with an average age of the subjects studied of 32.2 years.

Similarly, our population mainly comprises sea professionals with only 14% of leisure boaters. In Trendel's, it was 35% boaters. The difference lies in the selection criterion that we initially set as a minimum of 90 days of navigation per year to ensure subjects exposition to the triggering factors.

The vertical component of the movement of the boat is frequently found as to be a key factor favouring the onset of seasickness for 71% of the patients. This fact has already been known for many years [12] and remains true. Smells are another frequent contributory factor to the onset or the aggravation of seasickness (71% of patients). The mentioned smells come from fuel or exhaust gases, and also from the kitchens.

Failure is defined as the persistence of vomiting or the absence of progression of group according to the Graybiel and Miller scale. Indeed, the presence of vomiting automatically sends the patient to group 4 of the Graybiel and Miller scale. Of 28 subjects, 5 meet these failure criteria, i.e., a success rate of 82%. Trendel et al. [8], with the use of optokinetic rehabilitation, obtained 75% success according to the same success criterion. It seems that the combination of virtual reality and saccular stimulation by vertical movements makes it possible to achieve more interesting results. This deserves to be confirmed by a larger study, ideally prospectively.

In another previous study [10], on a larger population, both professional and recreational, the average age was 45 years. A significant improvement in seasickness had already been found after using optokinetic rehabilitation, the score dropping from 7.92 to 4.28.

In 2020, in this study of 141 patients [10], we addressed the notion of ability to work on board; essential element for professionals who, above all, want to be able to practice their profession and would not always have any other option in the event of inability. This often becomes for them a success criterion for the management of seasickness even if there is still discomfort or some symptoms of seasickness.

We have noticed an improvement in operational inability from 7.2 to 3.81, thanks to rehabilitation by optokinetic stimulation. Here we find a score that goes from 8.39 to 3.71 in our population after we have modified the rehabilitation technique by combining virtual reality with saccular stimulation. In 2017, another project carried out in our department on the rehabilitation of seasickness by visual simulation alone, pointed out an improvement from 8.2 to 3.6 [11].

Logically, there is a correlation between the intensity of the initial seasickness and the resulting inability to work on board. When the intensity of seasickness increases, the inability on board also increases by a coefficient of 0.59.

After treatment, the correlation between intensity of residual seasickness and working-on-board inability stands at 0.51, which seems to be of the same order as in the situation before treatment. On the other hand, the coefficient between intensity of residual seasickness and Graybiel scale after treatment is 0.697 whereas it was much less pronounced before. This is due to the very structure of the Graybiel scale and greater subject discrimination in first groups (slight malaise and moderate malaise).

The VAS will allow a more varied assessment of the intensity of seasickness, which can then explain this less pronounced correlation coefficient. Moreover, after treatment, the correlation between Graybiel score and working-on-board inability remains similar (0.38 before treatment and 0.36 after treatment).

CONCLUSIONS

The use of a simple VAS seems to be a good way to assess both the intensity of seasickness and the resulting inability to work on board. In the same way, it allows to assess the intensity of other motion sicknesses if they exist in the subject. The information thus obtained makes it easy to quantify motion sickness, in particular to assess the rehabilitation's effectiveness.

In a professional population, beyond the intensity of seasickness, it is the ability to perform one's job that is at stake. This is why, it is important to assess seasickness itself, and especially the working ability on board. Indeed, a slight or moderate discomfort with no effect on working ability can satisfy the patient even though seasickness persists.

The rehabilitating protocol allows a decrease in seasickness intensity and delays its onset. These first results reinforce our recommendation to combine navigation simulation in virtual reality with vertical movements that also stimulate the other organs of the inner ear, in particular the saccule. These results obtained with this innovative and unique method must be confirmed by a study on a larger population.

Moreover, given the variability of individual susceptibility to seasickness and the variability of the influence of extrinsic and intrinsic factors, it would be interesting to carry out a study analysing these different factors which are sometimes questionable (ethnicity, gender, etc.).

Finally, using simulation and virtual reality allows us to consider personalized care for each patient by adapting the simulation parameters to the specific characteristics of the boat on which the patient is working.

Conflict of interest: None declared

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